

What is claimed is:

1. A force provider comprising:
 - 2 a provider housing that defines a piston chamber, the provider housing including a first beam aperture, a first cylinder aperture that is in fluid communication with a fluid at a first pressure and a spaced apart
 - 4 second cylinder aperture that is in fluid communication with a fluid that is approximately at the first pressure; and
 - 6 a piston assembly including a piston positioned in the piston chamber, and a first beam extending through the first beam aperture, the piston including a first piston side and a second piston side, the first beam
 - 8 being secured to the first piston side, the piston moving relative to the provider housing along a piston path, wherein at a first piston region of the piston path, the piston is positioned between the first beam aperture and
 - 10 the first cylinder aperture and at a second piston region of the piston path, the piston is positioned between the cylinder apertures.
 - 12
 - 14
2. The force provider of claim 1 wherein the provider housing includes
 - 2 a second beam aperture, the piston assembly includes a second beam extending through the second beam aperture, the second beam being secured to the second
 - 4 piston side.
3. The force provider of claim 1 wherein at the first piston region, the
 - 2 pressure of the fluid on the first piston side is greater than the pressure of the fluid on the second piston side.
4. The force provider of claim 3 wherein at the second piston region,
 - 2 the pressure of the fluid on the first piston side is approximately equal to the pressure of the fluid on the second piston side.
5. The force provider of claim 4 wherein at a third piston region of the
 - 2 piston path, the pressure of the fluid on the second piston side is greater than the pressure of the fluid on the first piston side.

2 6. The force provider of claim 5, wherein in the third piston region, the
piston is positioned between the second cylinder aperture and a second beam
aperture in the provider housing.

2 7. The force provider of claim 1 wherein at the second piston region,
the pressure of the fluid on the first piston side is approximately equal to the
pressure of the fluid on the second piston side.

2 8. The force provider of claim 1 wherein at a third piston region of the
piston path, the pressure of the fluid on the second piston side is greater than the
pressure of the fluid on the first piston side.

2 9. The force provider of claim 8, wherein in the third piston region, the
piston is positioned between the second cylinder aperture and a second beam
aperture in the provider housing.

2 10. The force provider of claim 1 wherein a wall gap exists between the
piston and the provider housing so that the piston moves easily relative to the
provider housing.

2 11. A force provider assembly comprising the force provider of claim 1
and a fluid source that directs a fluid into the piston chamber near the first piston
region.

2 12. The force provider assembly of claim 11 wherein the amount of fluid
directed into the piston chamber by the fluid source is approximately equal to the
amount of fluid that escapes between the piston and the provider housing and
4 between the first beam and the provider housing.

2 13. The force provider assembly of claim 12 wherein the fluid source
directs fluid into the piston chamber so that the pressure on the first piston side
does not decrease when the piston is moving in a first direction in the first piston
4 region.

14. The force provider of claim 1 further comprising an intermediate
2 piston positioned within the piston chamber, the intermediate piston moving
concurrently with the piston when the piston is positioned in the first piston region
4 and wherein the piston moves relative to the intermediate piston when the piston
is positioned in the second piston region.

15. The force provider of claim 14 wherein the piston is not fixedly
2 coupled to the intermediate piston.

16. The force provider of claim 14 wherein the first bar extends through
2 the intermediate piston.

17. A stage assembly for moving a device along a stage path that
2 includes a first stage region and a second stage region, the stage assembly
comprising:

4 a stage that retains the device;
a mover that moves the stage along the stage path; and
6 the force provider of claim 1 coupled to the stage.

18. The stage assembly of claim 17 wherein the force provider provides
2 an acceleration/deceleration force on the stage when the stage is in the first stage
region and approximately no force on the stage when the stage is in the second
4 stage region.

19. The stage assembly of claim 18 wherein the stage path includes a
2 third stage region and the force provider provides an acceleration/deceleration
force on the stage when the stage is in the third stage region.

20. An exposure apparatus including the stage assembly of claim 17.

21. An object on which an image has been formed by the exposure
2 apparatus of claim 20.

22. A semiconductor wafer on which an image has been formed by the
2 exposure apparatus of claim 20.

23. A force provider assembly for use with a mover for moving a stage
2 along a stage path that includes a first stage region and a second stage region,
the force provider assembly comprising:

4 a pneumatic force provider coupled to the stage, the force provider
providing an acceleration/deceleration force on the stage when the stage is
6 in the first stage region and approximately no force on the stage when the
stage is in the second stage region.

24. The force provider assembly of claim 23 wherein the stage path
2 includes a third stage region and the force provider provides an
acceleration/deceleration force on the stage when the stage is in the third stage
4 region.

25. A force provider assembly of claim 23 wherein the force provider
2 comprises (i) a provider housing that defines a piston chamber, the provider
housing including a first beam aperture, a first cylinder aperture that is in fluid
4 communication with a fluid at a first pressure and a spaced apart second cylinder
aperture that is in fluid communication with a fluid at approximately the first
6 pressure; and (ii) a piston assembly including a piston positioned in the piston
chamber, and a first beam extending through the first beam aperture, the piston
8 including a first piston side and a second piston side, the first beam being secured
to the first piston side, the piston moving relative to the provider housing along a
10 piston path, wherein at a first piston region of the piston path, the piston is
positioned between the first beam aperture and the first cylinder aperture and at a
12 second piston region of the piston path, the piston is positioned between the
cylinder apertures.

26. A force provider assembly of claim 23 wherein the force provider
2 comprises (i) a provider housing that defines a piston chamber, the provider
housing including a first beam aperture, a second beam aperture, a first cylinder
4 aperture that is in fluid communication with a fluid at a first pressure and a spaced
apart second cylinder aperture that is in fluid communication with a fluid at
6 approximately the first pressure; and (ii) a piston assembly including a piston
positioned in the piston chamber, a first beam extending through the first beam

8 aperture and a second beam extending through the second beam aperture, the
piston including a first piston side and a second piston side, the first beam being
10 secured to the first piston side and the second beam being secured to second
piston side, the piston moving relative to the provider housing along a piston path,
12 wherein at a first piston region of the piston path, the piston is positioned between
the first beam aperture and the first cylinder aperture and at a second piston
14 region of the piston path, the piston is positioned between the cylinder apertures.

27. The force provider assembly of claim 26 wherein at the first piston
2 region, the pressure of the fluid on the first piston side is greater than the pressure
of the fluid on the second piston side.

28. The force provider assembly of claim 27 wherein at the second
2 piston region, the pressure of the fluid on the first piston side is approximately
equal to the pressure of the fluid on the second piston side.

29. The force provider assembly of claim 27 wherein at a third piston
2 region of the piston path, the pressure of the fluid on the second piston side is
greater than the pressure of the fluid on the first piston side.

30. The force provider assembly of claim 29, wherein in the third piston
2 region, the piston is positioned between the second cylinder aperture and the
second beam aperture.

31. The force provider assembly of claim 26 wherein a wall gap exists
2 between the piston and the provider housing so that the piston moves easily
relative to the provider housing.

32. The force provider assembly of claim 26 further comprising a fluid
2 source that directs a fluid into the piston chamber near the first piston region.

33. The force provider assembly of claim 32 wherein the amount of fluid
2 directed into the piston chamber by the fluid source is approximately equal to the
amount of fluid that escapes between the piston and the provider housing and
4 between the first beam and the provider housing.

2 34. The force provider assembly of claim 32 wherein the fluid source
4 directs fluid into the piston chamber so that the pressure on the first piston side
 does not decrease when the piston is moving in a first direction in the first piston
 region.

2 35. The force provider assembly of claim 23 wherein the force provider
4 further comprises a provider housing that defines a piston chamber, a piston
 positioned within the piston chamber and an intermediate piston positioned within
 the piston chamber, the intermediate piston moving concurrently with the piston
 when the stage is positioned in the first stage region and wherein the piston
6 moves relative to the intermediate piston when the stage is positioned in the
 second stage region.

2 36. The force provider assembly of claim 35 wherein the piston is not
 fixedly coupled to the intermediate piston.

2 37. A stage assembly for moving a device, the stage assembly
 comprising:
 a stage that retains the device;
4 a mover that moves the stage along the stage path; and
 the force provider assembly of claim 23 coupled to the stage.

2 38. An exposure apparatus including the stage assembly of claim 37.

2 39. An object on which an image has been formed by the exposure
 apparatus of claim 38.

2 40. A semiconductor wafer on which an image has been formed by the
 exposure apparatus of claim 38.

2 41. A force provider comprising:
 a provider housing that defines a piston chamber; and
 a piston assembly including a piston and a first intermediate piston
4 positioned within the piston chamber, the piston moving relative to the
 provider housing along a piston path that includes a first piston region and

6 a second piston region, wherein the first intermediate piston moves
concurrently with the piston when the piston is positioned in at least a
8 portion of the first piston region and wherein the piston moves relative to
the first intermediate piston when the piston is positioned in the second
10 piston region.

42. The force provider of claim 41 wherein the piston is not fixedly
2 coupled to the first intermediate piston.

43. The force provider of claim 41 further comprising a first bar that is
2 secured to the piston, the first bar extending through the first intermediate piston
and through the provider housing.

44. The force provider of claim 43 further comprising a first intermediate
2 bar that is secured to the first intermediate piston, the first intermediate bar
extending through the provider housing.

45. The force provider of claim 44 wherein the first bar extends through
2 the first intermediate bar.

46. The force provider of claim 41 wherein (i) the piston assembly
2 includes a second intermediate piston that is positioned within the piston chamber,
(ii) the piston path includes a second piston region, (iii) the second intermediate
4 piston moves concurrently with the piston when the piston is positioned in at least
a portion of the third piston region, and (iv) the piston moves relative to the second
6 intermediate piston when the piston is positioned in the first piston region and the
second piston region.

47. The force provider of claim 41 wherein the provider housing includes
2 a first beam aperture, a first cylinder aperture that is in fluid communication with a
fluid at a first pressure and a spaced apart second cylinder aperture that is in fluid
4 communication with a fluid that is approximately at the first pressure, and wherein
the piston assembly includes a first beam extending through the first beam
6 aperture, the piston including a first piston side and a second piston side, the first
beam being secured to the first piston side, wherein at the first piston region of the

8 piston path, the piston is positioned between the first beam aperture and the first
cylinder aperture and at the second piston region of the piston path, the piston is
10 positioned between the cylinder apertures.

48. The force provider of claim 47 wherein at the first piston region, the
2 pressure of the fluid on the first piston side is greater than the pressure of the fluid
on the second piston side.

49. The force provider of claim 48 wherein at the second piston region,
2 the pressure of the fluid on the first piston side is approximately equal to the
pressure of the fluid on the second piston side.

50. The force provider of claim 49 wherein at a third piston region of the
2 piston path, the pressure of the fluid on the second piston side is greater than the
pressure of the fluid on the first piston side.

51. The force provider of claim 50, wherein in the third piston region, the
2 piston is positioned between the second cylinder aperture and a second beam
aperture in the provider housing.

52. The force provider of claim 41 wherein a wall gap exists between the
2 piston and the provider housing so that the piston moves easily relative to the
provider housing.

53. A stage assembly for moving a device along a stage path that
2 includes a first stage region and a second stage region, the stage assembly
comprising:

4 a stage that retains the device;
a mover that moves the stage along the stage path; and
6 the force provider of claim 41 coupled to the stage.

54. The stage assembly of claim 53 wherein the force provider provides
2 an acceleration/deceleration force on the stage when the stage is in the first stage
region and approximately no force on the stage when the stage is in the second
4 stage region.

2 55. The stage assembly of claim 54 wherein the stage path includes a third stage region and the force provider provides an acceleration/deceleration force on the stage when the stage is in the third stage region.

56. An exposure apparatus including the stage assembly of claim 53.

2 57. An object on which an image has been formed by the exposure apparatus of claim 56.

2 58. A semiconductor wafer on which an image has been formed by the exposure apparatus of claim 56.

2 59. A method for accelerating and decelerating a stage that is moved along a stage path that includes a first stage region and a second stage region, the method comprising the step of:

4 coupling a pneumatic force provider to the stage, the force provider providing an acceleration/deceleration force on the stage when the stage is in the first stage region and approximately no force on the stage when the stage is in the second stage region.

2 60. The method of claim 59 wherein the stage path includes a third stage region and the force provider provides an acceleration/deceleration force on the stage when the stage is in the third stage region.

2 61. A method of claim 59 wherein the step of coupling includes the step of providing a force provider that comprises (i) a provider housing that defines a piston chamber, the provider housing including a first beam aperture, a first cylinder aperture that is in fluid communication with a fluid at a first pressure and a spaced apart second cylinder aperture that is in fluid communication with a fluid at approximately the first pressure; and (ii) a piston assembly including a piston positioned in the piston chamber, and a first beam extending through the first beam aperture, the piston including a first piston side and a second piston side, the first beam being secured to the first piston side, the piston moving relative to the provider housing along a piston path, wherein at a first piston region of the piston path, the piston is positioned between the first beam aperture and the first

12 cylinder aperture and at a second piston region of the piston path, the piston is
positioned between the cylinder apertures.

62. A method of claim 59 wherein the step of coupling includes the step
2 of providing a force provider that comprises (i) a provider housing that defines a
piston chamber, the provider housing including a first beam aperture, a second
4 beam aperture, a first cylinder aperture that is in fluid communication with a fluid
at a first pressure and a spaced apart second cylinder aperture that is in fluid
6 communication with a fluid at approximately the first pressure; and (ii) a piston
assembly including a piston positioned in the piston chamber, a first beam
8 extending through the first beam aperture and a second beam extending through
the second beam aperture, the piston including a first piston side and a second
10 piston side, the first beam being secured to the first piston side and the second
beam being secured to second piston side, the piston moving relative to the
12 provider housing along a piston path, wherein at a first piston region of the piston
path, the piston is positioned between the first beam aperture and the first cylinder
14 aperture and at a second piston region of the piston path, the piston is positioned
between the cylinder apertures.

63. The method of claim 61 wherein at the first piston region, the
2 pressure of the fluid on the first piston side is greater than the pressure of the fluid
on the second piston side.

64. The method of claim 63 wherein at the second piston region, the
2 pressure of the fluid on the first piston side is equal to the pressure of the fluid on
the second piston side.

65. The method of claim 64 wherein at a third piston region of the piston
2 path, the pressure of the fluid on the second piston side is greater than the
pressure of the fluid on the first piston side.

66. The method of claim 65, wherein in the third piston region, the piston
2 is positioned between the second cylinder aperture and the second beam
aperture.

2 67. The method of claim 62 further comprising the step of directing a fluid from a fluid source into the piston chamber near the first piston region.

2 68. The method of claim 59 further comprising the step of coupling a mover to the stage that moves the stage along the stage path.

2 69. The method of claim 59 wherein the step of coupling includes the step of providing a force provider that comprises (i) a provider housing that defines a piston chamber; and (ii) a piston assembly including a piston and a first intermediate piston positioned within the piston chamber, the piston moving relative to the provider housing along a piston path that includes a first piston region and a second piston region, wherein the first intermediate piston moves concurrently with the piston when the piston is positioned in at least a portion of the first piston region, and wherein the piston moves relative to the first intermediate piston when the piston is positioned in the second piston region.

2 70. The method of claim 69 wherein the piston is not fixedly coupled to the first intermediate piston.

2 71. A method for making an exposure apparatus comprising the steps of providing an illumination source, providing a stage, and accelerating and decelerating the stage by the method of claim 59.

2 72. A method of making a wafer including the steps of providing a substrate and forming an image on the substrate with the exposure apparatus made by the method of claim 71.